Assessing contamination of soil with PCBs and its health effect in Serpukhov (Moscow region)

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Introduction

Up to the mid 80s there was nothing special about the epidemiological indicators in Serpukhov, as compared with other industrial cities of Moscow region. The first indication that something was wrong was the increasing incidence of diathesis in infants. In 1988 the atopic dermatitis rate in the city was 45.4 cases per one thousand of children, which was by 2.6 times higher than the average in the Moscow region (Pleskachevskaya & Bobovnikova, 1992). Diathesis was registered primarily in children whose mothers lived in the vicinity of the science and production association (SPA) “Capacitor” or were employers of this enterprise. In many cases, the disease was cured only by abandoning breast-feeding. This led to a hypothesis that the reason of diathesis was the presence of toxicants in the breast milk of mothers, which, in turn, was due to the unsatisfactory sanitary situation at the SPA “Capacitor” and on the adjacent territory.

Site and methods

The experimental plant “Capacitor” that was part of the whole enterprise manufactured electric capacitors for different purposes. Starting from 1960 they were using PCBs as insulating liquid for filling capacitors. Therefore, it was fair to assume that PCBs were responsible for the detected adverse effects. The first analyses of environmental and breast milk samples for PCBs were carried out in 1986 in SPA “Typhoon” at the request of the State Committee on Sanitary Epidemiological Surveillance in Serpukhov, Serpukhov district and Puschino of Moscow region (SCSES), and they confirmed the soundness of this assumption.

Analytical determination of PCBs was based on application of the US EPA Guidelines SW-846 #8082, #608 and #1668A.

Reliability and comparability of results is insured by implementation of internal Quality Assurance/Quality Control (QA/QC) program, including:

Assessment of reproducibility of results;

Control of matrix effects (using surrogate bstandards);

Identifying courses of possible deviations and their elimination;

For each batch analysis is performed of certified reference materials, blank samples, replication of analysis of samples from the same batch.

Results and discussion

High levels of snow contamination with PCBs were revealed not only in the sanitary zone, but also in different directions at a distance of several kilometers from the plant. The concentrations of PCBs in water samples collected in different places of the city were as high as 14 maximum permissible levels (MPL) equal to 1 μg/l for water reservoirs. The analysis of breast milk in women living in the vicinity of the plant and working there revealed abnormally high levels of PCBs: in some samples the concentrations were as high as 990 to 2390 μg/l, while the tolerable level equals 25 μg/l (WHO, 1988). The concentrations of PCBs in breast milk of women working at a plant, but living in other parts of the city were somewhat lower (180 to 657 μg/l). These, however, were also above the tolerable level by tens of times. Thus it was established that the operations of the “Capacitor” plant resulted in significant releases of PCBs to the environment and a significant impact on human health in Serpukhov.

The results of breast milk analysis showed that apart from working at the plant, living near the plant is another important factor responsible for elevated levels of PCBs in people. That is why, the primary purpose of the wide scale studies was to evaluate the environmental contamination (soil, water, air) and contamination of foodstuff produced both within the city and outside (vegetables, eggs, sour cream, milk). The results of the performed studies showed that the most contaminated area in the city was the neighborhood of private houses bordering the plant site in the south. Over many decades people had been growing in their gardens agricultural products for their needs and for the local market. The maximum levels of soil contamination were reported at a distance from 300 m to 2.5 km from the plant on the banks of the Borovlyanka rivulet flowing in the ravine and dividing the neighborhood of private houses into two parts. Outside of the city, downstream of the point of confluence with the Oka River, the allotments of the “Yurievka” cooperative are located. The rivulet is the receiver of wastewater of the plant. In 1987 the PCBs

concentrations in the discharged wastewater were found to exceed MPL by 1270 times. Below the discharge point the PCBs concentrations in the rivulet water were exceeding MPL by 80 times. During spring floods the rivulet water enters the floodplain, which leads to additional yearly contamination of soil with PCBs. Furthermore, the owners of the allotments and gardens were actively using the water from the rivulet for irrigation, which resulted in formation of localized areas with abnormally high contamination. The PCBs content in soil along the rivulet banks was hundreds and thousands MPLs and the contamination level of the produce grown there (vegetable root crops, dill, parsley) was the highest in the city, with carrots being contaminated most of all: up to 9.5 mg/kg. The contamination levels for other vegetables were also high. The concentrations of PCBs in parsley, dill, spring onion were several mg/kg wet weight. The PCBs concentration in yolk of eggs collected in contaminated private yards was 100-200 times higher than in eggs bought in stores and originating from other regions. Similar to 1986, the breast milk samples of those living in the vicinity of the plant showed high concentrations of PCBs. Estimation suggests that an infant is exposed to PCBs levels exceeding the tolerable one (WHO, 1988) by tens and hundreds of times.

The studies conducted in Serpukhov in 1986-1987 demonstrated that the operations of the capacitor plant pose a major hazard for the plant workers and city residents, among them infants in the first place. As a consequence, the sanitary service of the city and of the Moscow region, with the support of the municipal authorities and the Committee on environmental protection, banned the use of PCBs for impregnation of capacitors.

After PCBs were no longer used, the study of the scale and implications of environmental contamination in Serpukhov was continued. Soil samples were collected in different parts of the city in children nurseries, hospitals, parks and holiday homes, flowerbeds and agricultural lands. In all 85 samples collected in 1988 the PCBs concentrations were higher than MPL (0.06 mg/kg). In other words, over the time of plant operations almost the whole city was affected by contamination to a greater or lesser extent. Further investigation in 1989-1992 showed that only about 10% of the city territory can be regarded as conventionally clean, while the MPL is exceeded at least by ten times on 50% of the territory. It may be worth noting that strongly contaminated spots were discovered in quite unexpected places and there was no homogeneity in the contamination.

In order to estimate PCBs intake by humans, the PCBs content was determined in foods available on the city market and in drinking water. In some samples of drinking water the PCBs concentrations were found to be above MPL of 1 μg/l (Drinking water, 1996). In addition to plant crops, the study objects included milk, sour cream and cottage cheese produced by the nearby diary firms. The PCBs concentration in milk was not high (up to 20 μg/l), but increased by tens of times when milk was reprocessed into sour cream and to a lesser degree with reprocessing into cottage cheese. The estimates of the municipal sanitary service showed that the daily intake of PCBs with food was several times above the norm. High concentrations of PCBs were discovered in blood of the plant workers. As might be expected, the higher levels of about 1000 μg/l were found in the workers engaged in impregnation operations. Thus, the studies conducted in 1988-1992 showed that the decision to stop using PCBs at the capacitor plant was justified and timely.

The investigation of the environmental contamination and epidemiological situation were resumed in Serpukhov in 1997 and are continued up to the present time within several international projects. Analysis of several tens of soil samples for PCBs shows that the contamination levels have not decreased significantly since the plant was closed. The impact of this contamination on human health was also studied. For the most contaminated areas adjacent to the plant site there is evidence of the increased disturbance of reproductive health of women, reduced hemoglobin level and erythrocytes in blood. Also post vaccination immunity in children and adolescents and increased mortality in the population in general were detected (Khakimov et al., 2000; Popova, 2000; Revich et al., 2000). It may be considered to be proved that all these adverse manifestations are results of high levels of PCBs in the environment and agricultural produce grown on the contaminated areas. Specifically, it was demonstrated that the likelihood of infertility increases with certainty with increase in PCBs level in blood of women (Revich et al., 2000).

The data available in SPA “Typhoon” on contamination of the environment and biological materials were entered in the database “Serpukhov”. This database contains a total of 1000 results of PCBs determinations in samples of different type. The database contains results of 360 determinations of PCBs in soil, 16 in air, 83 in water, 50 in snow and 70 in root vegetables, 14 in fruit, 33 in leaf vegetables, 33 in tree leaves and needles, 73 in eggs, 109 in breast milk and 20 in blood. The majority of the data were obtained in 1987-1992, and also in 1997 and 1999.

An important feature of PCBs contamination in Serpukhov is high heterogeneity of contamination. The contamination of the surface soil layer can differ by five orders of magnitude or so within one yard. The contamination is less heterogeneous on cultivated lands than on virgin ones, but even there a ten-fold difference may be expected. The discovered high heterogeneity of PCBs content in soil is indicative of the occurrence of localized contamination sources. Of them the principal sources are:

- leakage of PCBs during storage, transportation and use
- irrigation of agricultural lands with contaminated water from the Borovlyanka rivulet and from tanks used earlier for PCBs transportation and storage;
- sewage and waste waters from the site;

- inundation of the floodplain of the Borovlyanka rivulet during floods.

The available data on the long-term dynamics of PCBs content in the soils of Serpukhov are rather conflicting. Some samples collected in 1999 and 2001 in the same non-agricultural areas as those studied in 1992 showed somewhat decreased concentration of PCBs, but in other places it was practically unchanged or increased (Bobovnikova et al., 2000). This suggests that the redistribution of PCBs across the territory of Serpukhov continues up to the present time and secondly, no major increase in the total contamination level due to natural reasons should be expected in the near future.

The PCBs level was determined in 23 agricultural plant species. For potatoes the spread in bioaccumulation factor (BF) is several orders of magnitude, while in other cases the difference in the values for different areas is not more than several fold. There is no trend for decrease in PCBs accumulation with time. Vegetable leaf crops tend to accumulate organic substances primarily from the air. The values of BF for parsley indicate that no major changes occurred from 1988 to 1997 in the quantitative parameters of PCBs transfer from soil to plant leaves through the air. Accumulation of PCBs in vegetable root crops in 1997 was lower that in 1988. This can be due to PCBs aging effect and a decline in biological bioavailaibility as a result. However, in this case the PCBs concentration in the air above the soil should be decreasing with time too and, accordingly, contamination of leaf vegetables.

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